

Decision making in health and medicine

Integrating evidence and values



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Contents

	About the authors	vii
	Foreword	ix
	Preface	xi
	Acknowledgments	xiii
	List of abbreviations	xv
1	Elements of decision making in health care	1
2	Managing uncertainty	33
3	Choosing the best treatment	61
4	Valuing outcomes	88
5	Interpreting diagnostic information	128
6	Deciding when to test	157
7	Multiple test results	177
8	Finding and summarizing the evidence	214
9	Constrained resources	245
10	Recurring events	305
11	Variability and uncertainty	339
12	Proactive decision making: a way of life	364
	Index	381

Elements of decision making in health care

And take the case of a man who is ill. I call two physicians: they differ in opinion. I am not to lie down and die between them: I must do something.

Samuel Johnson

1.1 Introduction

How are decisions made in practice, and can we improve the process? Decisions in health care can be particularly awkward, involving a complex web of diagnostic and therapeutic uncertainties, patient preferences and values, and costs. It is not surprising that there is often considerable disagreement about the best course of action. One of the authors of this book tells the following story (Hunink, 2001):

Being a vascular radiologist, I regularly attend the vascular rounds at the University Hospital. It's an interesting conference: the Professor of Vascular Surgery really loves academic discussions and each case gets a lot of attention. The conference goes on for hours. The clinical fellows complain, of course, and it sure keeps me from my regular work. But it's one of the few conferences that I attend where there is a real discussion of the risks, benefits, and costs of the management options. Even patient preferences are sometimes (albeit rarely) considered.

And yet, I find there is something disturbing about the conference. The discussions always seem to go along the same lines. Doctor R. advocates treatment *X* because he recently read a paper that reported wonderful results; Doctor S. counters that treatment *X* has a substantial risk associated with it, as was shown in another paper published last year in the world's highest-ranking journal in the field; and Doctor T. says that given the current limited health-care budget maybe we should consider a less expensive alternative or no treatment at all. They talk around in circles for 10–15 min, each doctor reiterating his or her opinion. The Professor, realizing that his fellows are getting irritated, finally stops the discussion. Practical chores are waiting; there are patients to be cared for. And so the Professor concludes: 'All right. We will offer the patient treatment *X*.' About 30% of those involved in the decision-making process nod their heads in agreement; another 30% start bringing up objections which get stifled quickly by the fellows who *really* do not want an encore, and the remaining 40% are either too tired or too flabbergasted to respond, or are more concerned about another objective, namely their job security.

The authors of this book are all familiar with conferences like this. We suspect our readers also recognize the scenario and that they too have wondered, 'Isn't there a better way to make clinical decisions? Isn't there a better way for health professionals, policy makers, patients, and the general public to communicate with each other and talk things out when the going gets tough?'

This book is about our answer to these questions. The methods it presents are addressed to the needs of all decision makers in the health-care arena – patients; physicians, nurses, and other providers of clinical services; public health and hospital administrators; health-care payers in both the private and public sectors – and to the clinical and public health researchers whose job it is to offer all of these constituencies wise and reasoned counsel.

Health-care decisions have become complex. As recently as a century ago, a physician had only a narrow range of possible diagnoses, a handful of simple tests, and a few, mostly ineffective, treatments to choose from. For example, the first edition of the justly famous *Merck Manual* (1899) ran to 192 pages. Since then our understanding of disease processes and our ability to control them have vastly increased, but so too has the complexity of health-care decisions. The 1999 centennial edition of the *Merck Manual* runs to 2833 pages, although it is unquestionably only a digest of what is now known (Beers and Berkow, 1999).

While new treatments have improved the outcome for many conditions, and even eliminated some diseases such as smallpox, many treatments are 'half-way' technologies that improve a condition but do not cure. For example, in cancer, there are many new, useful but sometimes taxing treatments that improve the prognosis without curing. Along with this increase in management options, we now contemplate treatment in a broader range of diseases, from mild hypertension to major disfigurement. This combination of a broad range of illnesses and imperfect treatment options increases our potential to help, but it also increases costs and makes decision making more complex and difficult. In this chapter, we outline a systematic approach to describing and analyzing decision problems. This approach, decision analysis, is intended to improve the quality of decisions and of communication between physicians, patients, and other health professionals. Decision analysis is designed to deal with choice under uncertainty and so it is naturally suited to the clinical setting. We believe that decision analysis is a valuable tool for physicians and others concerned with clinical decision making, both for decisions affecting individual patients and for health policy decisions affecting populations of

patients. The ability of physicians collectively to command a vast array of powerful and expensive diagnostic and therapeutic interventions carries with it a social responsibility to use these resources wisely. Decision analysis is a systematic, explicit, quantitative way of making decisions in health care that can, we believe, lead to both enhanced communication about clinical controversies and better decisions. At a minimum, the methods we expound can illuminate what we disagree about and where better data or clearer goals are needed. At best, they may assure us that the decisions we make are the logical consequences of the evidence and values that were the inputs to the decision. That is no small achievement.

1.2 Decision making and uncertainty

Unlike most daily decisions, many health-care decisions have substantial consequences, and involve important uncertainties and trade-offs. The uncertainties may be about the diagnosis, the accuracy of available diagnostic tests, the natural history of the disease, the effects of treatment in an individual patient or the effects of an intervention in a group or population as a whole. With such complex decisions, it can be difficult to comprehend all options ‘in our heads,’ let alone to compare them. We need to have some visual or written aids. Hence a major purpose of decision analysis is to assist in comprehension of the problem and to give us insight into what variables or features of the problem should have a major impact on our decision. It does this by allowing and encouraging the decision maker to divide the logical structure of a decision problem into its components so that they can be analyzed individually and then recombine them systematically so as to suggest a decision. Here are two representative clinical situations that can be addressed with this approach:

Example 1

As a member of the State Committee for common childhood diseases, you have been asked to help formulate a policy on the management of chronic otitis media with effusions (also known as ‘glue ear’). Glue ear is the most common cause of hearing problems in childhood and can lead to delayed language development. It has been recognized for over a century, but in the 1900s the only available treatments were ineffective. For example, the British surgeon Astley Cooper recognized that an incision of the eardrum temporarily relieved the deafness, but the incision closed rapidly despite attempts to keep it open by inserting, among other things, a lead wire, fish bones, and a gold ring. We now have many treatment choices, including grommets (ventilation tubes; there are at least two major types), antibiotics, corticosteroids, and

hearing aids (Rosenfeld and Bluestone, 1999). However, since glue ear usually resolves spontaneously, you might also choose to do nothing, at least initially. Given these various treatment options, should your committee recommend monitoring for hearing loss, treatment with grommet insertion, or the use of hearing aids? For example, tympanometry, which measures the eardrum's ability to move, can be used as a monitoring tool, though an audiogram is needed to confirm the degree of any hearing loss. How do you proceed with formulating a recommendation? How can you systematically approach such a decision?

Example 2

A 70-year-old man with coronary artery disease is being evaluated for coronary artery bypass grafting (CABG). An ultrasound demonstrates an asymptomatic stenosis (a narrowing) of one of the carotid arteries leading to the brain. The decision faced by the team of physicians is whether to:

- (a) perform bypass surgery without further diagnostic workup or treatment of the carotid artery stenosis;
- (b) perform a special X-ray, a carotid angiography, and then a carotid endarterectomy (i.e., surgery to clear the obstruction in the carotid artery) prior to coronary artery bypass surgery;
- (c) perform angiography and then perform carotid endarterectomy during the same procedure as the bypass surgery.

Medical decisions must be made, and they are often made under conditions of uncertainty. Uncertainty about the current state of the patient may arise from erroneous observation or inaccurate recording of clinical findings or misinterpretation of the data by the clinician. For example, was the carotid artery stenosis really asymptomatic? Did the patient ever have a transient ischemic attack (temporary symptoms due to loss of blood flow to a region of the brain) that went unnoticed or that he interpreted as something else?

Uncertainty may also arise due to ambiguity of the data or variations in interpretation of the information. For example, if you repeated the ultrasound examination, would you get the same result? Uncertainty exists too about the correspondence between clinical information and the presence or absence of disease. The ultrasound is not perfect: how accurately does it indicate the presence or absence of a carotid artery stenosis? Some patients with a stenosis may be falsely classified as not having the disease, and some patients without a stenosis may be falsely classified as having the disease. Does our patient really have a carotid artery stenosis?

Finally, the effects of treatment are uncertain. In Example 1, there is

essentially no diagnostic uncertainty, but there is uncertainty about the outcomes of treatment and about whether a trial of watchful waiting might allow the glue ear to clear up without medical or surgical intervention and without harm to the child. An important uncertainty, therefore, is the natural history of the disease. In Example 2, there would be uncertainty about the outcome of treatment, even if the diagnosis is certain and the treatment is well established. The rate of treatment failure may be known, but in whom it will fail is unpredictable at the time the treatment is initiated. For our 70-year-old patient we cannot predict whether performing a carotid endarterectomy will really protect him from a stroke during the CABG (Ali et al., 1998).

To deal with the uncertainties associated with the decision problem you need to find the best available evidence to support or refute your assumptions, and you need a framework for combining all of these uncertainties into a coherent choice. In a decision analysis process we first make the problem and its objectives explicit; then we list the alternative actions and how these alter subsequent events with their probabilities, values, and trade-offs; and finally we synthesize the balance of benefits and harms of each alternative. We shall refer to this as the PROACTIVE approach (problem – reframe – objectives – alternatives – consequences and chances – trade-offs – integrate – value – explore and evaluate) to health-care decision making. This has three major steps, each with three substeps. (The steps are a modification of the PrOACTIVE approach suggested by Hammond et al. (1999) in their book *Smart Choices*.) Though we present this as a linear process, you should be aware that often iteration through some steps will be required, and that sometimes the solution will be apparent before all steps are complete.

1.3 Step 1 – PROactive: the problem and objectives

You should begin by making sure you are addressing the right problem. This first requires that you make explicit what the possible consequences are that you are seeking to avoid or achieve. This may not be straightforward, as there are often different ways of viewing the problem and there may be competing objectives. Exploring these dimensions before analyzing the alternative actions is important to steer the analysis in the right direction. After the initial attempt at defining the *problem*, you should *reframe* the problem from other perspectives, and finally, identify the fundamental *objectives* for any course of action.

1.3.1 P: Define the problem

What are your principal concerns? A good way to clarify management problems is to begin by asking, ‘What would happen if you took no immediate action?’ This simple question seeks to uncover the outcomes that you might wish to avoid or achieve. Carefully answering this question should lead to a description of the possible sequences of events in the natural history of the condition. You may need to follow up by asking ‘and what then?’ several times. For example, a common cause of a very rapid heart beat is paroxysmal atrial tachycardia or PAT (episodes of rapid heart beat initiated by the conducting system in the upper heart chambers). A patient with PAT will typically experience a sudden onset of rapid heart beat (around 200 beats/min), which ceases suddenly after minutes to hours. It is usually accompanied by some anxiety, since patients worry that there is something very wrong with their heart, but it usually causes no other physical discomfort. If a patient presents after such an episode, you may analyze the problem by asking: ‘What would happen if you took no immediate action?’ Patients with PAT are often concerned that it signals a problem with their heart. However, long-term follow-up studies of patients with PAT show that their risk of dying from heart disease is no different from that of the rest of the population (Aronow et al., 1995). So the natural history tells us that the real issue is not the risk of a heart attack or death, but the risk of recurrent episodes of PAT and the anxiety they induce.

Of course, many medical problems have much more serious consequences. Other problems we will consider as illustrative examples in later chapters include severe chest pain, abdominal aortic aneurysms (dilatation of the main abdominal artery), management of needlestick injuries, testing for the BrCa1 gene for breast cancer, and atrial fibrillation (an irregular heart beat that greatly increases the risk of stroke). Each of these problems has a complex sequence of uncertain but potentially serious consequences. Visual aids that help describe the problem include decision trees, state-transition diagrams, influence diagrams, and survival plots. These descriptions are necessarily schematic: just as a map is useful to describe a territory, these visual aids help chart the possible course of events. They are helpful in describing and communicating the consequences and hence help navigate the decision-making process. The most straightforward tool to begin with is a *consequence table*, i.e., a tabulation of the principal concerns. Table 1.1 shows this for the management options for glue ear.

DEFINITION

A *consequence table* tabulates the consequences of a choice and considers all relevant perspectives and important dimensions.

Table 1.1 Consequence table for the wait-and-see option for the problem of otitis media with effusion (glue ear)

Consequences	Wait-and-see option
Hearing	Slow improvement over months to years
Behavior	Poor hearing may lead to disruptive behavior
Language development	Delayed articulation and comprehension (with possible long-term consequences)
Acute middle-ear infections	Recurrent episodes
Long-term complications	Possible conductive problems

Source: Rosenfeld and Bluestone (1999).

1.3.2 R: Reframe from multiple perspectives

Does the problem look different from different perspectives? You should understand how the problem you are dealing with appears to others. In the clinical setting this requires that you broaden, at least temporarily, your focus from a disease framework to one that includes the concerns for the patient. In the context of public health this requires broadening your perspective to include the aggregate limits on resources, as well as the individual perspectives of the patient, the provider, the payer, and the public policy maker.

How does the problem of glue ear appear from different perspectives? You might consider different disciplinary perspectives. For example, biologically, glue ear is a problem of microbes, immune responses, and anatomical dysfunctions. From a psychological perspective, it is one of difficulties in language development. From a sociological perspective, it might be seen to be a problem of classroom behavior and family interactions. The child, the parents, the clinician, the teacher, and the health system will all view the problem differently and have overlapping objectives but with different emphases.

1.3.3 O: Focus on the objective

The main objective of health care is to avert or diminish the consequences of a disease. Sometimes this means prevention or cure; sometimes it may be slowing the disease's progress or preventing the disease's complications; sometimes it may be only the alleviation of symptoms or dysfunction. In our first example, only time will 'cure' the age-related anatomical problem

with the Eustachian tube that leads to glue ear, but meanwhile you may alleviate the major problem – deafness – by removing fluid from the middle ear, or you may simply use a hearing aid.

If you framed and reframed the problem appropriately, the pivotal concerns and objectives should have become apparent. However, before proceeding to develop and evaluate options, you should check that you have a clear idea of the objectives. What elements are of most concern to the patient or population? What are the short-term and long-term objectives and concerns, and how do these vary between patients? Sometimes these objectives are straightforward. For example, the objective of immunization decisions is to reduce morbidity and mortality from infectious diseases. However, often there are multiple competing objectives. For example, in managing patients with advanced cancer there may be competing objectives of comfort, function, and length of life, and these may be different for patient and caregivers. If there are trade-offs between the objectives, it is obviously important to understand what the objectives are.

When listing the objectives, you should clearly distinguish between *means objectives* and *fundamental objectives*. A means objective is an intermediate goal but which is only a stepping stone to what we truly value. In our second example, the coronary artery bypass surgery is not a goal in itself, but a means of achieving the fundamental objectives of improved quality of life (less angina, i.e., chest pain) and avoidance of early mortality.

The nature of objectives may be clarified by repeatedly asking ‘why.’ In our first example, you might consider that insertion of a ventilation tube will achieve the objective of resolving the glue ear, which may appear to be an objective. Why do you want the glue ear to resolve? Because that will lead to normal hearing. And why do you want normal hearing? Hearing is both an end in itself, and important for proper language development. Why do you want proper language development? That is something we intrinsically value, and hence it is a fundamental objective. Thus resolving the glue ear is a means objective, whereas normal hearing is both a fundamental objective (it has its own intrinsic value) and a means objective (it is needed for normal language development).

Understanding the fundamental objectives can help us generate options that achieve such objectives through different means. For example, focusing on hearing instead of the fluid in the middle ear suggests a hearing aid as one alternative to consider. Similarly, with the coronary artery bypass graft, you may need to step back and reconsider other options to manage the angina, such as angioplasty (balloon dilatation of stenosis of the coronary arteries) or better medical management. Committing too early to

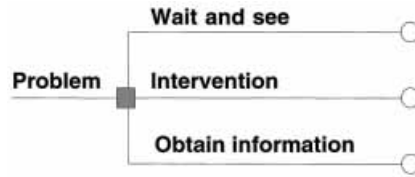


Figure 1.1 Generic decision tree for the initial decision node.

a means objective rather than the fundamental objectives can unnecessarily narrow our view of the possible options.

1.4 Step 2 – proACTIVE: the alternatives, consequences, and trade-offs

1.4.1 A: Consider all relevant alternatives

To be able to choose the best alternative in a particular circumstance, you need to know the range of reasonable alternatives. This list may be very long, so it is helpful to have a generic list. All alternatives may be placed in one of three categories: (i) a wait-and-see, watchful waiting, or a ‘do-nothing’ policy; (ii) initiate an intervention, e.g., treatment now; or (iii) obtain more information before deciding, such as ordering a diagnostic test or doing a population survey. These alternatives are illustrated in the decision tree of Figure 1.1.

The initial line is labeled with the population or problem you are considering (such as glue ear or coronary artery disease). The square represents a *decision node* at which just one of the several alternative actions, represented by the subsequent lines, must be chosen. At the decision node, the decision maker is in control. From each alternative action, there will usually be a subsequent chance node (the circles), with branches representing the possible outcomes of each option. The probabilities of events and outcomes will depend on the alternative chosen. The consequences of the other alternatives will be examined in the next step. We will have more to say about decision trees in Chapters 2 and 3.

You may have already developed the chance tree for the wait-and-see policy when describing the problem in Step 1. The consequences of the other alternatives will be examined in the next step. Before doing that, let us look in more detail at each of the three generic alternatives.

DEFINITION

A *decision tree* is a visual representation of all the possible options and the consequences that may follow each option.

1.4.1.1 Wait-and-see, watchful waiting, or do-nothing policy

A wait-and-see, watchful waiting, or do-nothing policy may take several forms. You may decide to do nothing about the condition. For example, this might be a reasonable choice for benign skin lesions or other variants of ‘normal.’ However, usually you will have a contingent policy that requires action depending on the disease course over time. The contingencies may be classified as either *monitoring*, where a regular check is made, or *triggering*, where you wait for a change in the type or severity of symptoms.

With monitoring, a check is made at fixed times to see whether the condition has improved, remained the same, or become worse. Action is then based on this progression. You may decide not to treat patients with mild hypertension until their blood pressure increases or they develop other risk factors; the criterion for action is the condition becoming worse. For the glue ear case, you may decide that action is required if no improvement is seen at 2 months; the criterion is either no change in the condition or a worsening. If a condition is unchanged, why should its persistence indicate a need for action? Imagine that there are two types of the condition: those that spontaneously resolve and those that never resolve. Waiting will allow us to differentiate these. Effectively this is a test of time. In reality, the groups will not be so distinct, and the test-of-time will be imperfect. So there will be a trade-off: delay may reduce the benefits for the persistent case but avoid the harm of unnecessary treatment for those who would resolve spontaneously. We will look at this trade-off more formally in Chapter 6.

With triggering, the patient is advised to return if particular events occur. If a patient has PAT, you may take action if the episodes become very frequent or if they are associated with chest pain or breathlessness (indicating that the heart is not coping with the rapid heart rate). In family practice this method is known as safety netting – a patient is instructed in the criteria required to catch a potentially ominous change. Clearly, wait-and-see is a strategy rather than a single action. Thus a *strategy* is a sequence of choices at decision nodes, contingent on the observed events at previous chance nodes. In some cases it may be useful to consider several different wait-and-see strategies.

1.4.1.2 Intervention

The next step is to list the active intervention alternatives, refraining from any evaluation of their merit at this point so that the full range of options can be considered. In the glue ear example, intervention would be treatment which may be aimed at cure, at arresting the progress of the disease,

at preventing complications, or at alleviating the symptoms. As described earlier, glue ear may be managed by attempting to resolve the effusion (cure), or by use of a hearing aid, which would alleviate the principal symptom and its consequences.

Where do you get the list of alternatives? Current knowledge, discussions with colleagues and experts, textbooks, and literature searches all contribute. An important component is a search of controlled trials, since these are often the source of the best-quality evidence on the benefits and risks of interventions. The Cochrane Controlled Trials Registry contains references and abstracts of many of the hundreds of thousands of controlled trials in health care. A search of the Registry for 'otitis media with effusion' (performed in 1999) provided 195 references with trials that include: (i) antibiotics, such as ceftibuten, cefixime, amoxicillin, and co-trimoxazole; (ii) oral corticosteroids, such as betamethasone, prednisolone, and prednisone; (iii) intranasal corticosteroids such as beclomethasone; (iv) nonsteroidal antiinflammatory drugs, such as naproxen and tranilast; (v) ventilation tubes (grommets) with two major different types; (vi) adenoidectomy; (vii) mucolytics such as carboxymethylcysteine and bromhexine; (viii) autoinflation (mechanical maneuvers which force air up the Eustachian tube); (ix) decongestants and antihistamines; and (x) hearing aids. Some of these options, such as antihistamines, are clearly ineffective. Others, such as mucolytics, autoinflation, and nonsteroidal antiinflammatory drugs, are of doubtful or uncertain value. The remaining treatments show a range of effectiveness and harms, which need to be compared in the next step.

1.4.1.3 Obtain information

If you are uncertain about the prognosis or diagnosis, further information, such as from a diagnostic test, may help in selecting the best intervention. In the area of public health, obtaining information may imply, for example, determining the prevalence of disease, doing a population survey, or measuring the level of a toxin. Useful information for making a clinical diagnosis may include symptoms, signs, laboratory tests, or imaging tests. Most tests will, however, produce some false-positive and false-negative results. In Chapters 5, 6, and 7, we will look in detail at interpreting such imperfect tests.

When the diagnosis is clear, testing may still help to clarify the prognosis or the responsiveness to treatment. With glue ear, the test-of-time helps by identifying those who are likely to have a sustained problem. Some tests specifically help to identify those most likely to respond. In women with

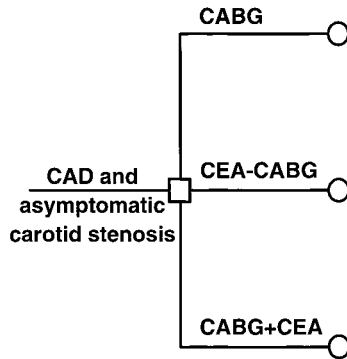


Figure 1.2

Decision tree fragment for Example 2: asymptomatic carotid artery stenosis in a male planned for coronary artery bypass grafting (CABG) for coronary artery disease (CAD). The options are: perform CABG only; perform carotid endarterectomy (CEA) and then CABG (CEA-CABG); or perform CABG and CEA in a combined procedure (CABG + CEA).

breast cancer, for example, the estrogen receptor status (i.e., whether or not the tumor cells have hormone receptors) of the cancer identifies cancers more likely to respond to hormonal treatments such as tamoxifen (Bland, 1999).

Figure 1.2 shows the start of a decision tree for our second example. In this example, the do-nothing option is to refrain from treating the carotid artery stenosis and proceed directly to CABG. There are at least two alternative treatment options: to either do a combined procedure, or to do the carotid endarterectomy first and then proceed to CABG.

1.4.2 C: Model the consequences and estimate the chances

You need to think through the sequence of consequences of each decision option and the chances of each event. Both short-term and long-term consequences should be considered. For each consequence you need to find the best available evidence to support your arguments. Having listed the alternatives, you next need to consider the consequences of each. This was partly accomplished when you outlined the natural history in Step 1, since natural history outlines the consequences of the do-nothing option. In Chapter 2 we will detail the types of probabilities you will encounter in decision making. These include the risks and benefits of interventions (Chapters 3, 8) and the accuracy and interpretation of diagnostic test information (Chapters 5, 6, and 7). Depending on the type of decision, the

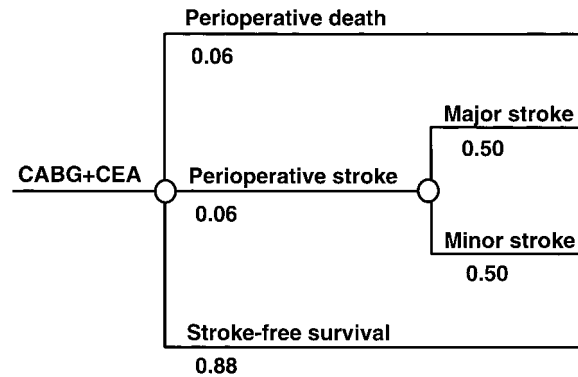


Figure 1.3

Chance tree for combined coronary artery bypass grafting (CABG) and carotid endarterectomy (CEA) (Example 2).

relevant outcomes may be identified based on the patient's values and preferences (Chapter 4) and/or the resource costs (Chapter 9).

Each alternative will lead to a different distribution of outcomes which need to be quantified. The relevant outcomes depend on the particular problem at hand. It may be the number of days of illness avoided or deaths prevented by a vaccine for influenza; or the chances of permanent hearing loss if glue ear is untreated; or the chances of 5- or 10-year stroke-free survival for the 70-year-old man with coronary artery disease and asymptomatic carotid artery stenosis. Some of the consequences may be better described in diagrams than words. For example, the possible consequences following the combined CABG and carotid endarterectomy operation for our patient in Example 2 might be described as in Figure 1.3, which shows one representation of the *chance tree*.

The round circles (chance nodes) are used to indicate time points at which there are two or more possible outcomes. Several sequences of chance nodes may be needed to describe a problem. For Example 2, choosing to do the combined CABG and carotid endarterectomy might result in one of three possible outcomes. Which of the three occurs is beyond our control. However, the likelihood of each can be indicated by the probabilities shown below the branches emanating from the chance node. We will return to the simple mathematics of probability in Chapter 2; for now, note that the probabilities are all between 0 and 1 (or between 0% and 100%, if expressed as percentages), and the sum of the probabilities of all of the branches from a single chance node adds up to 1 (that is, 100%). This reflects the fact that one, and only one, of the possibilities at each chance node may occur. From each chance arm, there may either be a

DEFINITION

A *chance tree* is a visual representation of a series of random discrete linked events. It visualizes the chance that each event can occur.

DEFINITION

A clinical balance sheet tabulates the consequences of different options and considers all relevant perspectives and important dimensions.

further division into possible outcomes, such as the major or minor stroke shown in Figure 1.3, or further decisions to be made. The decision tree thus assists in structuring the sequence of choices and outcomes over time.

Sometimes consequences are simple. For example, in patients who have had ventricular fibrillation (a fatal arrhythmia unless resuscitation is given), the main concern is sudden death from a recurrence. Decisions about appropriate drugs or implantable defibrillators will focus around this obviously important outcome. Many disease conditions, however, involve multiple consequences. For these, comparison of the benefits and harms across different options is assisted by a clinical balance sheet.

Table 1.2 provides an example of a balance sheet for some of the alternatives for managing glue ear. Usually, the first alternative will be a wait-and-see strategy and the balance sheet will then incorporate the consequence table from Step 1 (Table 1.1). The subsequent columns will show the consequences of each alternative. Note that the probabilities of uncertain outcomes are also included, e.g., the spontaneous resolution rate and the complication rates.

The balance sheet can be assembled by either describing the outcomes with each alternative, or by describing the relative effects of each alternative (relative to the wait-and-see strategy). Both methods are reasonable, and often one will be more convenient than the other. However, only one method should be used within a single table to insure consistent interpretation of the information presented.

The table will also describe the potential harms and resource costs of treatment alternatives. These harms and costs will include: (i) the direct burden or discomfort from the intervention; (ii) the complications and adverse effects of the intervention; and (iii) the cost to the health-care system, patients, and their families, including management of any complications. The direct burden may vary considerably. This burden might also include changes in the patient's self-perception. For example, the burden of a diagnosis of hypertension includes not just the taking of a daily medication but also the change in self-perception which has been shown to result in increased sick days taken and poorer career progress. The complications can range from minor dose-related side-effects to major surgical complications or drug reactions. Finally, the burden to the health-care system is the cost of the intervention, including personnel, materials, overheads, and costs to patients and families (see Chapter 9).

Table 1.2. Clinical balance sheet for some options for managing glue ear

	Alternatives		
	Monitor (wait-and-see)	Grommet insertion (short-term tube)	Hearing aid
<i>Potential treatment benefits</i>			
Improve hearing and behavior	Slow improvement of months to years (resolution at 1, 3, and 6 months is 60%, 74%, and 88%)	Rapid improvement with grommet until it falls out in 8 months (range 6–12 months)	Immediately improved
Language development	Delayed (possibly permanent)	‘Normal’	‘Normal’
Acute middle-ear infections	1–2 episodes per year	Reduced by 0.5 episodes per year	1–2 episodes per year
Long-term complications of glue ear	Uncertain: possible conductive problems	Uncertain effects	Uncertain: possible conductive problems
<i>Potential treatment harms and costs</i>			
Long-term complications of treatment	None	Tympanosclerosis (scarred drum): 40% Retraction: 18% Grommet lost into middle ear ^a : 0.4% Perforation ^a : 0.4%	None
Restrictions	None	(Some) swimming restrictions while grommet in place	Need to wear hearing aid
Short-term complications	None	Ear discharge: Brief: 40% Chronic: 5%	None
Cost	Low	\$2400	\$600–1500

^aThese complications will require further surgery to retrieve the grommet or patch the perforation.

1.4.3 T: Identify and estimate the value trade-offs

Valuation of consequences becomes important when there is more than one type of consequence. If you are only concerned with a single adverse consequence, such as mortality, then the issue is simply a question of which

alternative offers the lowest (expected) probability of that consequence or the highest probability of survival. If there are several disparate consequences, however, the choice of alternative might depend on how we value them. With the alternatives for managing glue ear, the inconvenience and perhaps embarrassment of wearing a hearing aid must be weighed against the small probability of complications from grommet insertion. Such trade-offs require clarification of the values involved. In some problems values can be clarified by trying out one of the alternatives. For example, a child with glue ear might borrow a hearing aid to test practicality and satisfaction with the results. Information about the experience of others may also be helpful in deciding whether an alternative is worth trying. In a study of 48 English children with glue ear, 71% reported complete satisfaction with a hearing aid and experienced improved speech and hearing.

Many decisions do not allow such a trial period. A common dilemma is a treatment that offers relief of symptoms but at a small risk of serious adverse consequences. Example 2 is a vivid illustration of this issue. There is a measurable risk of perioperative mortality to be balanced against the better quality of life and longevity to be gained with successful surgery. Other examples include: total hip replacement for severe arthritis, a procedure which relieves pain and can restore mobility but has a small risk of operative mortality or major complications; nonsteroidal antiinflammatory drugs, which provide relief for several conditions but with a very small risk of stomach bleeding; and a blood transfusion which may relieve symptoms of anemia but at small risks of a transfusion reaction or blood-borne infection. Because of the processes for drug and device approval in place in most of the industrialized world, the benefits are likely to outweigh the adverse consequences for most commonly used treatments. However, the balance will depend on the individual's prognosis and severity as well as on the magnitude of the potential harms and the strength of each individual's outcome preferences. For example, women with the BrCa1 gene are at greatly increased risk of breast cancer, and this risk may be decreased by undergoing bilateral mastectomy. Clearly this is an individual decision and women may have very different values and attitudes about the risks and outcomes of each choice. Methods for quantifying preferences and values are discussed in Chapter 4. Resource constraints limit the ability of health care to meet all the needs of patients and society and the method of cost-effectiveness analysis (also known as cost–utility analysis) is the topic of Chapter 9.

1.5 Step 3 – proactive: integration and exploration

Once the probabilities and values of each outcome have been identified, it is time to figure out which option is best. To do this we may need to calculate the expected value, that is, the average value gained from choosing a particular alternative. The option with the highest expected value will generally be chosen, provided we have captured the major decision elements in the analysis. However, you should also explore how sensitive the decision is to the exact probabilities and values chosen. Let us look at these three subcomponents.

1.5.1 I: Integrate the evidence and values

After explicitly formulating the problem, the options, and the associated risks, benefits, and values, it sometimes becomes obvious which option is optimal. Further analysis is unnecessary. But this is not always the case. If there are multiple dimensions, a useful next step is to focus on the important differences between options. To do this with the clinical balance sheet you might first rank the issues in order of importance. The re-arranged table on glue ear – with only the two active treatment options – is shown in Table 1.3, with the rankings done separately within the benefits and harms. Next, those rows for which the consequences are fairly even may be struck out. These consequences can be ignored, as they are not altered by the available choices. For the treatment of glue ear, the simplified table suggests that grommet insertion has more complications and slightly greater expense than a hearing aid but reduces the number of acute middle-ear infections.

The balance sheet can help tease out the different dimensions of a problem. However, for some dimensions the sequence of events is complex and will be better represented by a chance tree. To summarize the consequences will require a formal calculation of the expected value of each option. In addition, in problems that involve both valuations and probabilities, the decision can be aided by calculating the expected value.

The process of calculating expected values is described further in Chapter 3. Furthermore, we may want to take quality of life into account, and calculate the expected quality-adjusted life years, which will be described in Chapter 4. Sometimes we will want to consider two different dimensions of the outcomes simultaneously and separately calculate the expected value for each. For example, in Chapter 9 we will incorporate costs, separately

DEFINITION

The *expected value* of an option is the sum of the values of all the consequences of that option, each value weighed by the probability that the consequence will occur.

Table 1.3. Balance sheet with rows in order of importance

	Alternatives	
	Grommet insertion (short-term tube)	Hearing aid
<i>Potential treatment benefits</i>		
Language development	Normal	Normal
Improve hearing and behavior	Rapid improvement with grommet until it falls out in 8 months (range 6–12 months)	Immediately improved
Long-term complications of glue ear	Uncertain effects	Uncertain: possible conductive problems
Acute middle-ear infections	Reduced by 0.5 episodes per year	1–2 episodes per year
<i>Potential treatment harms and costs</i>		
Long-term complications of treatment	Tympanosclerosis (scarred drum): 40% Retraction: 18% Grommet lost into middle ear ^a : 0.4% Perforation ^a : 0.4%	None
Restrictions	(Some) swimming restrictions while grommet in place	Need to wear hearing aid
Short-term complications	Ear discharge: Brief: 40% Chronic: 5%	None
Cost	\$2400	\$600–1500

^aThese complications will require further surgery to retrieve the grommet or patch the perforation.

calculating expected benefits and expected economic costs, allowing us to calculate the cost per unit of benefit gained.

1.5.2 V: Optimize the expected value

You have now evaluated each alternative, but which should you choose? Decision analysis employs an explicit principle for making choices: maxi-

mize expected utility. The complex and sometimes conflicting information about outcomes, harms, and benefits represented in our list are combined and integrated by a multiplication-and-addition procedure: the probability of each outcome is multiplied by its value, and for each alternative, these products are added. You obtain an expected value for each alternative, and these expectations are the basis for recommending one.

In theory, you should prefer the alternative with the best net expected benefit, that is, the one that appears to give the best overall utility taking into account both the chances and value of each consequence. If the outcome values have been expressed as desirable values, we would want to maximize the expected value. If the outcome values have been expressed as undesirable values, we would want to minimize the expected value. Other decision goals are defensible, especially if you think that some especially important objectives or features of the problem have not been included in the analysis. For example, in some situations, some decision makers prefer to minimize the chance of the worst outcome (a minimax strategy). This ‘fear-of-flying’ strategy focuses on avoiding a single catastrophic outcome without regard to its probability. It would rule out total hip replacement for hip arthritis because of the small risk of operative mortality, and would eschew medication for anything but life-threatening illnesses because of the small risk of an adverse reaction that was worse than the illness being treated. Precedent, authority, habit, religious considerations, or local consensus may also play a part in making a decision. We think that the approach we have described, which leads to the maximum net expected benefit, should generally be preferred because it balances considerations of the harms and benefits of all outcomes, weighed by the probability that they will occur.

1.5.3 E: Explore the assumptions and evaluate uncertainty

The approach we have described uses numbers to talk about both the probabilities and values of treatment outcomes. Clearly some of these numbers will be well established in the clinical literature, while others may be very ‘soft.’ You may not be sure they are really right. You may be uncertain about whether some probabilities retrieved from the literature apply to our patient, or, if you have to estimate some key probabilities, you may be uncertain about the accuracy of our estimates or concerned about various cognitive biases that have been shown to affect probability estimates (Bogardus et al., 1999; Chapman and Elstein, 2000). If you have

consulted patients to elicit their values and preferences, you may be uncertain about the stability of the numbers obtained from these inquiries, especially if the patients have been asked to evaluate health states they have not yet experienced (Fischhoff et al., 1980; Christensen-Szalanski, 1984). What if some or all of these numbers were different? Would our decision change? How much change in any of these numbers will change the recommended decision? Or is the recommendation insensitive to any plausible change in either the probabilities or the utilities?

To understand the effects of these uncertainties on our decision, you should perform a ‘what-if’ analysis, also known as a *sensitivity analysis*. By varying the uncertain variables over the range of values considered plausible, you can calculate what the effect of that uncertainty is on the decision. If the decision is not sensitive to a plausible change in a parameter value, then the precise value of that parameter is irrelevant. If the decision does change, this warrants further study to find out more precisely what the value is. In Example 2, a sensitivity analysis for age and perioperative risk in a published decision analysis (Cronenwett et al., 1997) could enable a decision maker to apply the results to her particular case, or to gain confidence that her decision was best. A quantitative, formal sensitivity analysis permits us to gain insight into what particular variables really drive a decision. If the key variables causing changes are probabilities, we say the decision is ‘probability-driven.’ More research may be needed to get better or more updated evidence. If the decision hinges on values and preferences, it is said to be ‘utility-driven.’ These uncertainties cannot be resolved by better evidence, because they are not about the facts. But they can be ameliorated by values clarification: whose values are at issue? How clear are the decision makers about what they really want? Do they understand the trade-offs that may be involved? Many recently developed decision aids for patients aim to assist in clarifying the patient’s values and understanding of the treatment options.

1.6 Using the results

What is the end product of this decision process? You might consider that ‘the decision’ is the major outcome. However, the insight gained will be useful for other similar decisions. So you should explicitly consider how to capture this insight for future use.

So, how can you apply the results of an analysis to other patients or target populations? Future patients may differ in many ways, so it is not usually the decision that is reapplied but rather the analysis process. Elements of the problem that, if different, are likely to change the decision